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AVAILABILITY AND NUTRITIONAL VALUE OF *CYMOPTERUS* (APIACEAE) ROOTS IN THE COLORADO STEPPE

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ABSTRACT.—The density, collection rate, dry weight, and nutritional content of *Cymopterus montanus* and *C. acaulis* (Apiaceae) roots were determined. The density of each species at three landscape positions in steppe vegetation was usually less than one plant/m^2. The exception was 3.8 *C. acaulis* plants/m^2 on ridgetops. In areas where *Cymopterus* plants were common the maximum density, dry weight, and root collection rates were 27 plants/m^2, 5.1-6.6 g/root, and 0.9 roots per minute for *C. montanus* and 12 plants/m^2, 1.5-1.6 g/root, and 0.7 roots per minute for *C. acaulis*. In both species the roots had 43-45% of dry weight as fiber, 20-25% digestible carbohydrate, and 1-2% nitrogen. Sucrose was the main sugar in both species. The total sugar content of dry, skin-free roots was 11.7% of dry weight for *C. montanus* and 4.4% for *C. acaulis*. The sugar contents of *Cymopterus* roots, sugar beets and roots of several other Great Plains species were compared. Ecological aspects and the potential cultivation of *Cymopterus* species are also discussed.

RESUMEN.—Se determinó la densidad, tasa de recolección, peso seco y valor nutritivo de los raices de *Cymopterus montanus* y *C. acaulis*. Las densidades promedio para ambas especies fueron de menos de una planta/m^2 en todas las areas de praderas no perturbadas excepto en las cimas de lomados donde la densidad de *C. acaulis* fue de 3.8 plantas/m^2. En áreas donde las plantas de *Cymopterus* eran abundantes las densidad máxima, el peso seco y la tasa de recolección fueron de 27 plantas/m^2, 5.1-6.6 g/tubérculo y 0.9 tubérculos por minuto para *C. montanus* y de 12 plantas/m^2, 1.5-1.6 g/tubérculos y 0.7 tubérculos por minuto para *C. acaulis*. Estas especies, en terminos del peso seco, conteníán 43-45% de fibre, 20-25% de carbohidratos y 1-2% de nitrógeno. El azucar más común en ambas especies fue la sacarosa. El contenido total de azúcares en los tubérculos sin cáscara fue de 11.7% en *C. montanus* y 4.4% en el caso de *C. acaulis*. El contenido en azúcares fue comparado con el de la remolacha azucarera y el de otras especies nativas. Se discuten tambien algunos aspectos ecológicos y la posibilildad de cultivar *Cymopterus*.

RESUME.—La densité, le taux de collection, le poids sec et la valeur nutritive des racines de *C. acaulis* et *C. montanus* ont été détermines. La dénsite de chaque espèce a trois differentes zones de la steppe de végétation est habituellement moins d'une plante par m^2. L'exception est 3.8 plantes/m^2 sur la cime des collines dans les zones oú les plantes de *C. acaulis* est répandues. Dans les lieux ou l'espèce *Cymopterus* est répandue, la densite maximale, les poids sec et le taux de collection des racines etaient de 27 plantes/m^2, 5.1-6.6 g/racine, et 0.9 g/minute pour

C. montanus et 12 plantes/m^2, 1.5–1.6 g/racine, et 0.7 g/minute pour *C. acaulis*. Chez les deux espèces les racines contenaient 43–45% de leur poids sec en fibres, 20–25% en hydrates de carbone digestible et 1–2% d'azote. Les racines ont été analysées pour quatre sucres, le sucrose s'est avéré le plus abondant chez les deux espèces. La teneur en sucre des racines epluchees a ete 11.7% dupoids sec pour *C. montanus* et 4.4% pour *C. acaulis*. Une comparaison du contenu en sucre des racines de *Cymopterus*, de la betterave a sucre et de plusieurs autres especes des hautes plaines a été effectuée. Les aspects éologiques et le potentiel de culture du *Cymopterus* ont été discutés.

INTRODUCTION

The best known root crops in the Apiaceae are carrots (*Daucus carota* L.) and parsnips (*Pastinaca sativa* L.), native to Europe, and *Arracacia xanthorrhiza* Bancroft from South America. Although no North American species in the Apiaceae have yet been domesticated, roots from plants in the genus *Lomatium* have been important staples for many Indian groups in Western Canada and North America. Roots from plants in the genus *Perideridia* are still eaten by Indians in the interior parts of the Pacific states (French 1971). This paper examines edible roots of two *Cymopterus* species that could have been a seasonally important food source to indigenous groups in the shortgrass steppe region of the Great Plains: *Cymopterus acaulis* (Pursh) Raf. and *Cymopterus montanus* (Nutt.) T. & G.

Most of the 48 species in the genus *Cymopterus* occur in mountain areas and have small geographical distributions (Hartman, pers. comm. 1990). By comparison, the geographical ranges of *C. acaulis*, *C. macrorhizus* Buckl. and *C. montanus*, the only three *Cymopterus* species reported in the Flora of the Great Plains (McGregor 1986), are much greater. Since wider ranges imply greater familiarity and availability to indigenous groups, the utilization of Great Plains *Cymopterus* species was probably greater than that of species that occur only in isolated mountain areas.

Spanish and English speaking persons have attributed vernacular names to *Cymopterus* plants based on plant names familiar to them. For example, common names for *Cymopterus* listed by Harrington (1967) include biscuit root, corkwing, wafer parsnip, and wild celery. The Spanish name "camote" was reported for *C. montanus* by Hedrick (1972), but this name is more commonly applied to *Ipomoea batatas* (L.) Lam., the sweet potato. In like fashion, *Cymopterus* roots have been called prairie turnips, a name more often used for *Psoralea esculenta* Pursh (Kindscher 1987), even though neither *Psoralea* nor *Cymopterus* are in the Brassicaceae, the family of *Brassica rapa* L., the garden turnip. Currently, the common names for *Cymopterus* are seldom used or known. In contrast to English and Spanish common names, Indian names for *Cymopterus* (none were found) would be of greater significance since such names would be from people that lived off the land for food, fiber and medicine.

The few ethnobotanical accounts of *Cymopterus* species are from Indian groups in the western and southwestern United States. These accounts are qualitative, brief, and usually refer to edible roots and/or shoots. Ten *Cymopterus* species reported by Harrington (1967), Havard (1895), Hedrick (1972), and Yanovsky (1936) to have edible greens and/or roots are: *C. acaulis*, *C. bulbosus* A. Nelson, *C. globosus* (S. Wats.) S. Wats., *C. glomeratus* CD, *C. longipes* S. Wats., *C. montanus*, *C. newberryi* (S. Wats.) M.E. Jones, *C. purpurascens* (A. Gray) M.E. Jones, *C. purpureus* S. Wats., and *C. fendleri* A. Gray. In Hedrick (1972) Sturtevant described the roots of *C. montanus* as "spindly-shaped, parsnip-like but much softer, sweeter and more tender than the parsnip." *Cymopterus fendleri* roots were reported by Yanovsky as a condiment for meat, by Hedrick as a flavoring of mutton, and by Havard as a condiment "with a pleasant anisate volatile oil ... used to flavor meats and make bitters ..." Morton (1963) indicated that *Cymopterus* roots were best in early spring and when boiled. Presumably in reference to root size and quality, *C. globosus*, *C. glomeratus*, and *C. montanus* have been identified as the best-known esculents in the genus (Havard 1895). Other accounts report that photosensitization can occur in poultry from ingestion of *C. watsonii* or *C. longipes* leaves and seeds (Egyed and Williams 1977; Vankampe *et al.* 1969). Stermitz *et al.* (1975) identified furocoumarins as a photosensitizing chemical in *C. watsonii*. Finally, insecticidal properties have been attributed to a boiled water extract of *Cymopterus* roots by Sweet (1976).

This study was undertaken to determine the collection rates, field densities, and nutritional value of *C. montanus* and *C. acaulis* roots (Fig. 1) in the Northern shortgrass steppe region of the United States. These species were selected because of reports of their utilization by indigenous groups and, in the case of *C. montanus*, because it is reported as one of "best known esculents" in the genus (Hedrick 1972).

FIG. 1.—*Cymopterus acaulis* (left) and *C. montanus* (right) excavated in northeastern Colorado on May 7, 1989.

SITE DESCRIPTION

Field work was conducted during the spring of 1988 and 1989 at the Central Plains Experimental Range (CPER), an area with native shortgrass steppe vegetation that is administered by the USDA Agricultural Research Service. The CPER is located 8 km north of Nunn, CO (latitude 40° 49 N, longitude 104° 46 W) at 1,650 m elevation. Mean annual precipitation from 1969-1988 was 322 mm (standard deviation of 74 mm), but approximately 80% of annual precipitation occurs from April to September.

To characterize soil conditions, soil samples were collected from three locations where *C. montanus* plants were abundant. At each location three soil subsamples were collected from around *C. montanus* roots at a depth of 5-15 cm. Subsamples were combined to a single sample per location and were analyzed at the Colorado State University soil testing laboratory (Workman *et al.* 1988). The analyses indicated that all three locations had sandy clay loam soil. The ranges in soil properties at the three areas were: pH 6.4-7.2, organic matter 1.6-2.1%, N 6-9 ppm, P 1-7 ppm, K 171-238 ppm, Zn 0.2-0.3 ppm, Fe 5.5-11.5 ppm, Mn 6.0-12.8 ppm and Cu 0.7-1.0 ppm.

MATERIALS AND METHODS

Field densities of *C. montanus* and *C. acaulis* plants were estimated at nine undisturbed steppe locations in late April 1988 and at three disturbed steppe locations in early May 1989. The undisturbed locations were three ridgetop, three midslope, and three toeslope or lowland positions. Disturbed locations, selected on the basis of abundant *C. montanus* plants, were adjacent to a corral, along a road, and by a fence. At each location all *C. acaulis* and *C. montanus* plants in 50 randomly placed 0.25 m^2 quadrats were tallied. To estimate maximum field densities the five quadrats from the disturbed sites with the highest tallies of *C. montanus* were averaged. Since *C. acaulis* was uncommon in disturbed sites, the maximum field density for this species was the average density of the five quadrats with the highest densities from undisturbed sites.

In 1988 one *Cymopterus* root in or near every fifth quadrat was excavated until 41 *C. montanus* and 10 *C. acaulis* roots were collected. Each root was washed, air dried for 24 hours and weighed. Roots were then cut open, oven dried at 50°C for 7 days and reweighed with and without the less palatable root skins. Eight samples of dry *C. montanus* tissue (five roots each) and two samples of *C. acaulis* tissue (five roots each) were analyzed at Colorado State University for nitrogen, fiber, and digestible carbohydrate. Nitrogen extraction used the methods of Nelson and Sommers (1980). The fiber analyses procedure of Waldren (1971) identified neutral detergent fibers such as hemicellulose, cellulose, and lignin. The carbohydrate values were non-structural carbohydrates (Smith *et al.* 1964) that included sugars, dextrin, starch, and fructusans. Fiber and carbohydrates values were expressed as percent dry weight.

Root collection rates for both *Cymopterus* species were determined at the three disturbed sites by excavating as many roots as possible during 15 minutes. The collection pace was steady, not hurried, as roots were removed from the soil by digging with a sharpened stick. A stick is an implement similar to that available to indigenous persons, e.g. pronghorn antelope tine. From the excavated plants four *C. montanus* and three *C. acaulis* roots were selected at random and analyzed for individual sugar contents at the USDA/ARS Crops Research Laboratory in Ft. Collins using their standard, but unpublished analytical technique (Susan Martin, pers. comm. 1990). This technique involved peeling each root and hand-grating the skin-free portion to obtain a fine "sawdust" or brei. To about 2 g brei, glass-distilled water was added at a ratio of about 1:6 (w/w) brei:water; the exact weights of brei and water were recorded. The brei-water mixture was homogenized for 30 seconds (Brinkmann UltraTurrax), swirled to wash down container walls, and homogenized another 30 seconds. The mixture was filtered successively through Whatman No. 1, a 1.2μ m membrane filter, and a 0.45μ m membrane filter. Samples (20μ L aliquots) were analyzed by HPLC on an ion exchange column in the calcium form (Waters Sugar Pak I), held at 85°C and eluted by 0.2mM calcium EDTA. Eluted components were detected by refractive index and quantified by electronic integration. The HPLC system was standardized daily with a series of standards that incorporated glucose, fructose, sucrose, and raffinose. Roots not selected for sugar analyses were weighed fresh, oven dried at 50°C for 7 days and weighed dry to estimate the water content of fresh roots.

Voucher specimens were made for *C. montanus* (*Hazlett 4651,* CS) and *C. acaulis* (*Hazlett 4652,* CS). Statistical differences between means for field densities, dry weights, and chemical contents were determined by t-tests.

RESULTS

At all three landscape positions in undisturbed steppe the density of *C. montanus* was $<$1 plant/m^2 (Table 1). The density of *C. acaulis* was also $<$1 plant/m^2 at toeslope and midslope positions, but was 3.8 plants/m^2 on ridgetops, significantly higher ($P < 0.05$) than at other landscape positions for this species and significantly higher than *C. montanus* at any location. Because disturbed sites were selected on the basis of abundant *Cymopterus* plants, the densities of *C. montanus* plants increased to a mean of 2.1 plants/m^2 in disturbed areas. The maximum density at disturbed sites was 39 plants/m^2 for *C. montanus.* The maximum density for *C. acaulis* occurred in undisturbed steppe and was 17 plants/m^2. All tallied individuals were sprouts from perennial roots and no juvenile plants of either species were encountered.

The mean dry weight of *C. montanus* roots, including skin, increased from 5.1 g/plant at undisturbed to 6.6 g/plant at disturbed sites. At both locations these values were significantly greater ($P < 0.05$) than the 1.5-1.6 g mean dry weight of *C. acaulis* roots from undisturbed and disturbed sites. For *C. montanus* and *C. acaulis* roots, the water content of fresh roots, including the skin, was 61% and 36% respectively. For individual roots the weight of the skin was 30% of total dry weight for *C. montanus* and, due to less root mass, 41% of total dry weight for *C. acaulis.*

TABLE 1.—Means and ranges in dry weight and densities of *Cymopterus montanus* and *C. acaulis* roots at different topopositions in native or "undisturbed" steppe and at disturbed steppe locations.

	Cymopterus montanus		*Cymopterus acaulis*	
	Mean	Range	Mean	Range
Dry wt (% of fresh wt)	38.5	—	64	—
Dry wt/root (g)				
—Undisturbed*	(27) 5.1	0.6–8.9	(10) 1.6	0.2–2.9
—Disturbed*	(40) 6.6	0.9–8.2	(33) 1.5	0.1–2.6
Density: Undisturbed steppe (plants/m^2)				
—3 Ridgetops*	0.4	0.0–0.6	3.8	0.3–7.6
—3 Midslopes	0.7	0.6–0.8	0.4	0.3–0.5
—3 Toeslopes	0.4	0.0–1.1	0.9	0.0–2.6
Density: Disturbed sites (plants/m^2)				
—All 3 areas*	2.1	1.8–2.4	1.0	0.5–1.4
—Maximum densities*	27	12–39	12	10–17

*Differences between means are significant ($P < 0.05$).
Values in parentheses are the number of samples.

Since the skin portion of *Cymopterus* roots is not very palatable, only the skin-free, white root tissue was used in calculations of food availability to humans. In undisturbed, randomly sampled steppe vegetation the amount of white root tissue was 1.4-2.5 g/m^2 for *C. montanus* and 0.7 g/m^2 for *C. acaulis*. However, based on mean root dry weights and mean maximum field densities in disturbed areas the availability of white root tissue was as high as 125 g/m^2 for *C. montanus* and 11 g/m^2 for *C. acaulis*. The collection rate for *C. montanus* at disturbed locations was 11-15 roots per 15 minutes (0.9 roots per minute). For *C. acaulis* at the same locations the collection rate was 10-12 roots per 15 minutes (0.7 roots per minute). Therefore, in areas where *C. montanus* is abundant, as much as 250 g of white, edible root tissue can be gathered in an hour.

Chemical analyses of plant tissue indicated that skin-free *C. acaulis* roots had a significantly higher nitrogen content than *C. montanus* (Table 2). However, *C. montanus* had significantly higher ($P < 0.05$) glucose and sucrose contents than *C. acaulis*. Total sugar content on a fresh weight basis was 4.5% for *C. montanus* and 2.8% for *C. acaulis*. On a dry weight basis the total sugar content was 11.7% for *C. montanus* and 4.4% for *C. acaulis* (Table 2). For both species sucrose was the most abundant sugar, constituting at least 88% of total sugar content. The average caloric content of sugars per 100 g of dry tissue, using the sucrose value of 3.9 calories/g of sugar, was 0.45 Cal/g for *C. montanus* and 0.17 Cal/g for *C. acaulis*.

TABLE 2.—Means and ranges in fiber, nitrogen, carbohydrate and sugars composition for naturally occurring *Cymopterus montanus* and *Cymopterus acaulis* roots from northeastern Colorado.

% of dry wt.	*Cymopterus montanus* Mean	Range	*Cymopterus acaulis* Mean	Range
Fiber[a]	44.6	32–54	42.8	36–49
Nitrogen[a]	1.0	0.7–1.2	1.6*	1.3–1.9
Carbohydrates[a]	24.4	18–29	20.3	16–25
Sugars:[aa]				
Raffinose	0.05	0–0.11	0.02	0.01–0.04
Glucose	0.08	0.04–0.16	0.03*	0.02–0.04
Fructose	0.18	0.10–0.25	0.07	0.05–0.09
Sucrose	11.28	9.88–14.89	4.25*	3.92–4.80

[a]n = 8 for both species.

[aa]n = 4 for *C. montanus;* n = 3 for *C. acaulis.*

*Significant differences (P 0.05) between species.

DISCUSSION

Compared to sugar contents of underground tissues from other native Great Plains plant species the 11.7% value for *C. montanus* was more than twice as high as the 5.6% sugar content reported for *Psoralea esculenta* (Kaldy *et al.* 1980) or the 4.4% sugar content reported herein for *C. acaulis.* On the other hand, the 11.7% sugar content in *C. montanus* was less than the 16.2% reported for *Perideridia gairdneri* (Hook. & Arn.) Mathias or 51.6% for *Helianthus tuberosus* L. (Kaldy *et al.* 1980). Except for *H. tuberosus,* all these values are less than a 35% dry weight sugar content reported for early European cultivars of white sugar beets, *Beta vulgaris* L. (Coons 1936). In nearly 200 years of selection the sugar content of *B. vulgaris* cultivars has been increased to approximately 80% of dry and near 16% of fresh weight. Cultivar selections for high sugar contents among native Great Plains plants would stan from a much higher initial sugar content for *H. tuberosus* and could conceivably double the sugar content of *Cymopterus* roots.

In contrast to studies that document only nutritional contents of wild collected roots (Kaldy *et al.* 1980; King and Gershoff 1987) this study also quantified densities and collection rates of *Cymopterus* roots from naturally occurring populations. A maximum field density of 125 g/m^2 of edible *C. montanus* tissue is of interest for several reasons. First, this value is similar to 100 g/m^2, an average value for aboveground annual net primary production in steppe vegetation (Sims and Singh 1978). Therefore, in some steppe locations the availability of edible *Cymopterus* roots is greater than average annual aboveground biomass production. Another implication of high concentrations of *Cymopterus* roots is credence to reports that these roots, relatively high sugar, were utilized by indigenous people. Finally, when native plants occur naturally in dense stands they have a greater possibility of adapting to dense stands in crops or gardens.

Although *Cymopterus* roots are a concentrated source of carbohydrate energy, only once was a *Cymopterus* root seen that was excavated; it apparently had been removed and eaten by a rodent. Furthermore, few roots showed any sign of damage by insects or pathogens. Since minimal damage occurs to *Cymopterus* roots in dense, naturally occurring populations, an important implication is that these plants could also be relatively insect and pathogen free in the aggregated condition required for gardens or crops. The absence of insect damage on any of the excavated or peeled roots also accented the observation of insecticidal properties for *Cymopterus* reported by Sweet (1976). Perhaps insect-repelling chemicals occur in *Cymopterus* roots. If so, they may be concentrated in the skin, another reason to remove the skin before consumption. In addition, allelopathic chemicals may be dispersed from roots into the soil, such as when *Cymopterus* plants die, and afford a degree of protection from herbivores to this root or to roots of neighboring plant species. Of special interest in this regard is the possibility that larva of *Phyllophaga* beetles, a pest of native rangeland grasses (Haws 1982), may avoid areas where *Cymopterus* roots occur or have occurred.

Available information on the life-history of *C. montanus* and *C. acaulis* indicates that *Cymopterus* plants are the first steppe species in northeastern Colorado to flower each spring, in March and April, and are the first perennial plants to disperse fruits (Dickinson and Dodd 1976). This study has further determined that although these two *Cymopterus* species often occur together, there are habitats where one or the other is more abundant: *C. acaulis* is more abundant on ridgetops and *C. montanus* is more abundant in areas of human disturbance. Since there was exposed shale on ridgetops, deeper water penetration associated with rocky soil may help explain greater ridgetop densities of *C. acaulis*. Greater water availability related to the absence of competing plants may also contribute to the success of *C. montanus* in disturbed areas. Although soil water availability may favor plant establishment on ridgetops and in disturbed habitats, the timing and extent of water availability probably differ between these locations. Also, seed dispersal differentiation may occur because the corky, winged *C. montanus* fruits appear to be more easily carried by rainwater than are fruits of *C. acaulis*. Finally, the fact that *C.montanus* roots store nearly four times more carbohydrates than *C. acaulis* roots may help explain the difference in habitat preference between these two species.

Indigenous persons usually preferred fruits and seeds as a food resource over underground storage organs such as *Cymopterus* roots (Bates 1985). However, in steppe vegetation fruits and seeds are scarce early in the year, the time when *Cymopterus* roots are most available. During the spring *Cymopterus* roots are probably the most abundant source of human food of any native steppe plant. Later in the year the roots are still there, but plants are difficult to locate because all aboveground tissue withers and dies. While other plant species with edible underground tissues occur in the shortgrass steppe, e.g. *Allium textile* A. Nels. & Macbr., *Glycyrrhiza lepidota* Pursh, *Liatris punctata* Hook. and *Psoralea tenuiflora*

Pursh, the density and concentration of food per unit area for each of these species alone or even combined is probably less than that of C. *montanus*.

CONCLUSIONS

This study has presented new information on the ecology and nutritional properties of two *Cymopterus* species native to the shortgrass steppe region of the Great Plains. Since these are native, edible plants it is important to document their nutritional value for people and to discuss their domestication potential. In terms of sugar content, C. *montanus* has a relatively high sugar content and may eventually be cultivated, perhaps as a xeric, home garden plant. Ecological characteristics of C. *montanus* plants that encourage domestication include natural occurrence in aggregated populations, low water requirements, food availability early in the spring, and a popular demand for native plant species. Obstacles to domestication include lack of knowledge on growth rates, life history, chemical composition, propagation techniques, and cultural acceptance. A next step in evaluating this species for human consumption is to test for possible toxic chemicals, such as those that occur in other *Cymopterus* species.

Finally, the collection rates of *Cymopterus* roots by indigenous persons probably did not exceed the values reported here. Since the incidence of disturbed steppe habitats, locations where C. *montanus* are most dense, have increased in the last century, the availability of *Cymopterus* roots as a wild-collected food source may be greater now than at any time in the past.

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